CRII: CPS: Wearable-Machine Interface Architectures

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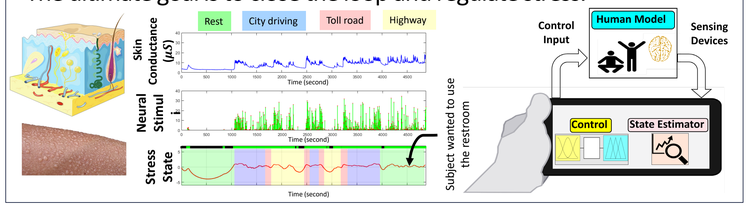
Project URL: **C**omputational**M**edicine**L**ab.ece.uh.edu/**NSF-CISE-CRII-CPS**-project

Challenges

- Stress is "The Health Epidemic of the 21st Century".
- Changes in heart rate, blood pressure, cortisol level, and skin conductance often accompany high levels of stress.

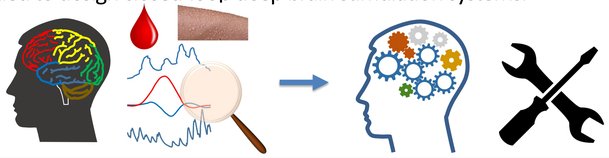
- Skin conductance and serum cortisol levels follow similar dynamics, involving **sparse neural stimuli** from the brain and an **underlying physiological system.**
- To track the stress state of an individual, inference of the sparse neural stimuli and the identification of the underlying physiological system is important.
- The ultimate goal is to close the loop and regulate stress.



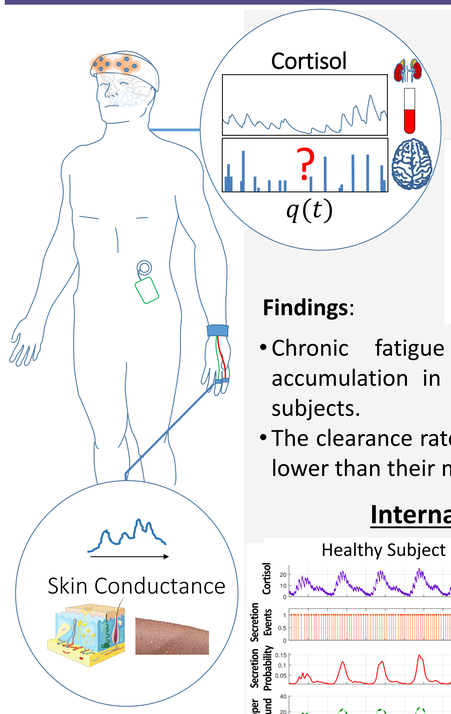
Scientific Impact

- Sparse deconvolution can be applied to problems in multiple domains (e.g. pulsatile hormone signal recovery, ventricular depolarization detection in electrocardiograms (EKGs), calcium imaging, electroencephalogram (EEG) sleep spindle detection).
- State-space methods enable tracking human emotions and behavior within a system-theoretic framework where the ultimate goal is to design controllers for different applications such as treating neuropsychiatric disorders including Post Traumatic Stress Disorder (PTSD).

- Inferring the underlying neural mechanisms and reconstruction of mental-stress-related brain dynamics through wearable devices could potentially be extended to design closed-loop deep brain stimulation systems.



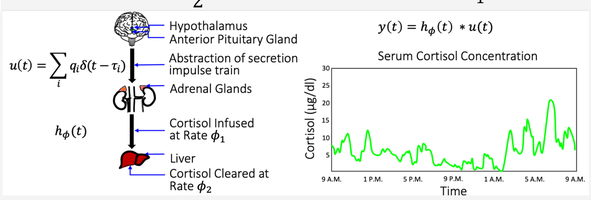
Solution



Cortisol Deconvolution

System-Theoretic Optimization Problem:

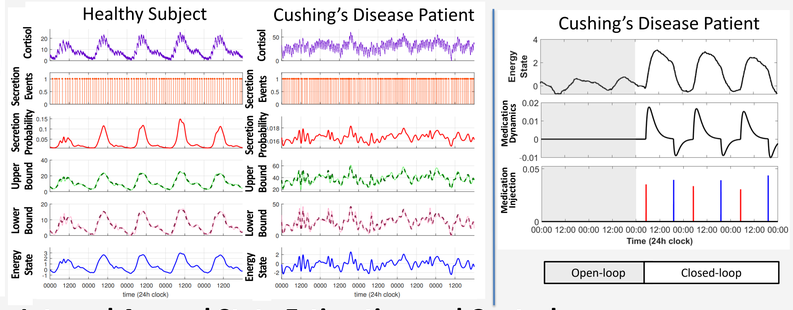
$$min \quad J_\lambda(\theta, \boldsymbol{q}) = \frac{1}{2}\|\boldsymbol{y} - F_\theta x_0 - D_\theta \boldsymbol{q}\|_2^2 + \lambda||\boldsymbol{q}||_1$$



Findings:

- Chronic fatigue syndrome patients have lower serum cortisol accumulation in the morning as compared to their matched healthy subjects.
- The clearance rate of cortisol by liver in fibromyalgia syndrome patients is lower than their matched healthy subjects.

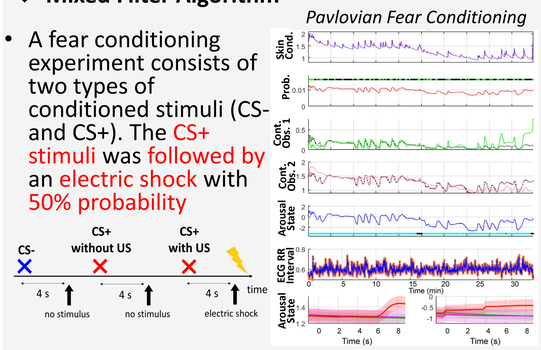
Internal Energy State Estimation and Control



Internal Arousal State Estimation and Control

❖ **Mixed Filter Algorithm**

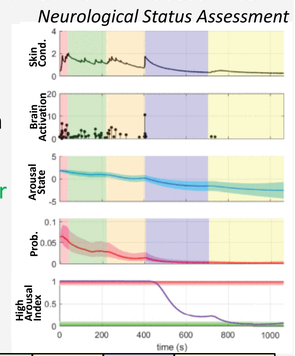
- A fear conditioning experiment consists of two types of conditioned stimuli (CS- and CS+). The CS+ stimuli was followed by an electric shock with 50% probability



❖ **Marked Point Process Filter**

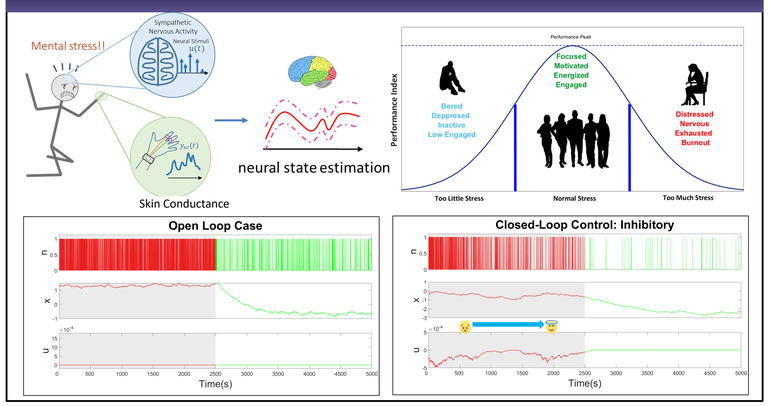
- Counting task: Count backward in 7s
- Stroop test: Name of a color is written on the screen but the ink color does not match the color name. Subject should identify ink color not color name

Green Red Blue
Hello Beautiful World



Instruction | Counting task | Stroop test | Relaxation | Emotional stress

Solution Continued



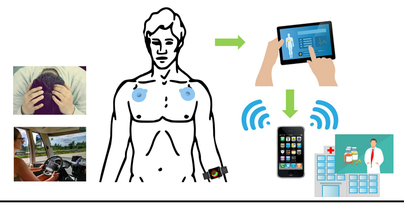
Societal and Quantified Impact

- Each year 43.8 million adults in the US experience mental illness.

18.1% anxiety disorders

6.91% major depression

1.1% schizophrenia



Educational and Outreach Impact

Over **130** girls visited our lab in **2018** and **2019** for our outreach events.

Educational videos for **2021** virtual Girls Engineering the Future.

- **10** journal articles, **14** conference papers, and **2** one-page invited conference papers.
- This research has been integrated into PI's courses; the course projects have resulted in **3** conference papers and **36** educational videos.
- **5** senior design teams have been designing wearable-machine interface architectures.
- **1** business school team has worked on the technology transfer for this research.
- **8** Undergraduate Research Projects (Honors Thesis, REU, Summer Undergraduate Research Fellows, and Independent Study).
- PI gave several laymen talks about this research to general audience and broader community
- PI served as a panelist to guide Montgomery Community College students through their career paths
- Physiological signal variations have been examined in:
  - Students taking exams for performance assessment,
  - Collaborations with the School of Theater and the College of Hotel Management for investigating emotions during acting and when learning the art of professional culinary tasting.

2021 NSF Cyber-Physical Systems Principal Investigators' Meeting
June 2-4, 2021

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